# AN ELECTRONIC INSTRUMENT FOR THE STUDY OF PHOTOCONDUCTIVE BEHAVIOR OF X-IRRADIATED SUBSTANCES AND THE VISUAL REGISTRATION OF DIFFRACTION PATTERNS

BY

EUGENE P. BERTIN, JR.

B.S., University of Illinois, 1948
M.S., University of Illinois, 1949

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN CHEMISTRY
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## ACKNOWLEDGMENT

The work to be described in this thesis transgresses the ill-defined boundaries of chemistry and invades the fields of electronics and physics. Moreover, the construction of the equipment involved more than ordinary skill in such highly specialized arts as glassworking and machining. Consequently, without the help of others, this project could never have progressed as far as it has.

The writer therefore takes the greatest pleasure in gratefully recognizing here the generous cooperation of the many people from whose assistance he benefited in this project:

Various phases of the glassworking were done by R.N. Waggener, of the Vacuum Tube Research Laboratory, Electrical Engineering Department, L.F. Goodyear, of the Chemistry Department, and C.E. Kling and R.E. Sterritt, of the Physics Research Laboratory.

The electron guns were provided and suitably modified to meet the writer's requirements by A.B. Wilson, also of the Vacuum Tube Research Laboratory.

A.E. Vatter, of the Electron Microscope Laboratory, Chemistry Department, assisted with the vacuum evaporation of some of the photoconducting surfaces, and freely offered advice on the design and operation of the vacuum equipment.

Certain metal parts of the equipment were machined by A.E. Wood and V.F. Walters, both of the Chemistry Department, and the latter also allowed the writer free use of his shop facilities throughout the project, and was himself of constant assistance.

The many persons who gave advice and assistance in various minor, but still important ways, must go unnamed, but no less appreciated.

Most of the funds for this not inexpensive project were provided by the Chemistry Department.

Above all, the continued advice, guidance, encouragement, interest, and unreserved backing of his adviser and friend, Dr. George L. Clark, have been most gratifying and deeply appreciated.

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## I. Introduction

The problem of pickup and visual presentation of x-ray diffraction patterns by wholly electronic means has apparently not been suggested in any publication. Other groups, working in the very closely related field of electronic intensification of x-ray fluoroscopic images, have not noted the potential applicability of their work to x-ray diffraction (2) (6).

The proposal involves some sort of electronic video (picture) pickup, communication, and reproduction system, probably similar in principle to types now widely used in television. A highly simplified video system is shown in Fig. 1A and the analogous system for x-ray diffraction patterns in Fig. 1C.

The present investigation is restricted to consideration of this problem as applied to x-ray diffraction technics of the simple, fixed-flat-film, transmission type (Fig. 1B) — i.e., "pinhole", Laue, and flat-film rotation technics. It is pointed out that even thus restricted, an electronic pickup and presentation system would have great value *per se* in research, industry, and education, and as an adjunct to more complex single-crystal methods. There is, however, no inherent reason why the method cannot be extended to include such diffraction technics as the flat-film Weissenberg and Buerger-precession methods as well.

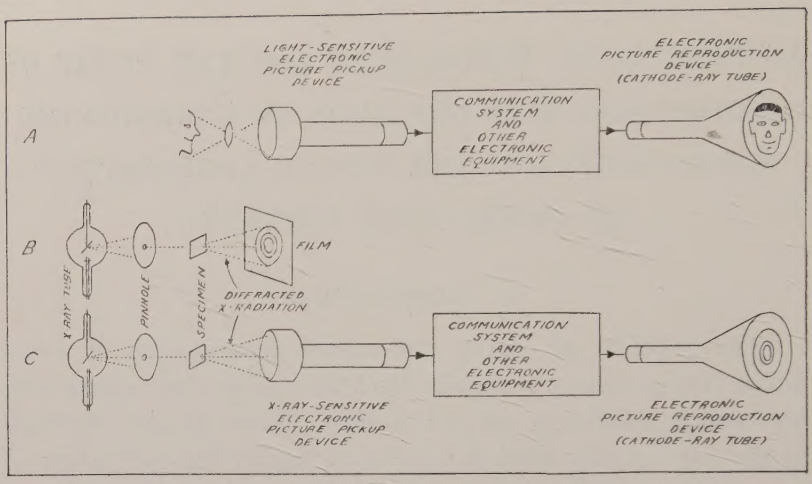


Fig. 1.

A. Video (Picture) System.
B. X-Ray Diffraction System (Transmission Method).
C. System for Electronic Pickup and Presentation of X-Ray Diffraction Patterns.

## II. General Consideration Of The Problem Of Electronic Picture Pickup And Presentation

The theory of electronic picture pickup and presentation is considered in general. The construction and operation are described of the electron image tube and of the other prototype electronic picture pickup tubes that have been developed to highly satisfactory degrees of performance for television service: the image dissector, iconoscope, orthicon, image orthicon (9), and vidicon (11). Several modifications of the iconoscope, e.g., the image iconoscope, are described to show how a prototype tube can be modified to improve its sensitivity and the quality of its transmitted picture.

## III. General Consideration Of The Problem Of Electronic Picture Pickup And Presentation As Applied To X-Ray Diffraction Patterns

With the foregoing chapter as background, the problems

inherent in television pickup are compared with those inherent in the pickup of x-ray diffraction patterns, and in the light of this comparison, the performances of the pickup devices are considered.

The quantitative aspect of the problem of pickup of x-ray diffraction patterns is given attention both with respect to numbers and energies of x-ray quanta any proposed electronic pickup system would be called upon to register.

A system, proposed by the writer, for pickup of x-ray diffraction patterns, using a multiplier phototube scintillation counter and mechanical scanning, with either electro-mechanical or cathode-ray presentation, is described. This system was not constructed in connection with the present investigation because of its serious inherent limitations.

The applicability to x-ray diffraction of the work of other groups, engaged in electronic intensification of x-ray fluoroscopic images, is considered (2) (6).

Possible ways are described and considered of applying to the present problem television-type pickup tubes in conjunction with fluorescent screens, and of using such tubes with x-ray-sensitive, instead of light-sensitive, photoelements. In the latter connection, the relative applicability of x-ray photoconductivity and x-ray photoemissivity is discussed, and a review of the literature on x-ray photoconductivity included. Particular emphasis is placed upon the remarkable x-ray photoconductivity of cadmium sulfide (4).

## IV. Experimental Work

As an outcome of the considerations of the preceding chapters, and particularly in view of the encouraging behavior of cadmium sulfide, it was decided to approach the probelm of electronic pickup of x-ray diffraction patterns from the avenue of an x-ray photoconductive, cathode-ray-type pickup tube — i.e., an x-ray-sensitive vidicon (11). The particular contribution of this thesis to this long-range objective is the design and

construction of equipment with which the photoconductive behavior of certain x-irradiated substances can be investigated under the conditions actually existent in a picture pickup tube (3) (10).

The general idea of the equipment finally constructed is shown in block-diagram form in Fig. 2 and consists of:

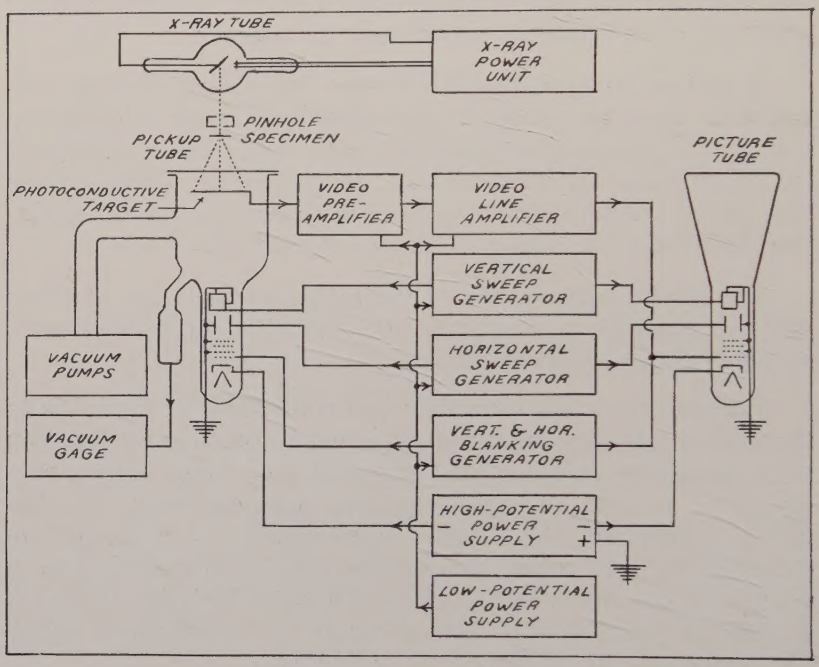


Fig. 2.
Equipment for Experimental Work.

1) X-ray equipment capable of producing x-radiation of the desired wavelength at high intensities. A Machlett AEG-50T tube having a molybdenum target and operating at 40 kv, 10-50 ma was used.

2) A conveniently demountable glass vacuum chamber, provided with a cathode-ray-type electron gun, to serve as a cathode-ray photoconductive pickup tube in which surfaces of

various x-ray-photoconductive materials may be examined under actual video conditions.

3) Vacuum pumps, gage tubes, and measurement equipment for producing and monitoring the vacuum in the demountable tube.

4) A cathode-ray picture tube for reproducing the pictures transmitted by the demountable pickup tube.

5) Suitable electronic equipment for performing the following functions:

a) Amplification of the video (picture) signal transmitted by the pickup tube.

b) Vertical and horizontal deflection of the scanning electron beams in both the pickup and picture tube.

c) Vertical and horizontal blanking of the scanning beams in both tubes.

d) Provision of high d.c. potential for the focusing and accelerating anodes of the electron guns in both tubes.

e) Provision of d.c. plate and grid potentials and a.c. heater supply for the tubes in all the foregoing electronic circuitry.

6) Various cables and coupling devices for interconnection and control of the various units.

The cathode-ray picture tube and all the electronic circuitry listed above are combined into a single monitor unit (5) (8).

Also developed in connection with the present investigation were technics for preparing suitable photoconductive targets, and experimental technics and procedures for the photoconductive studies. Targets of sulfur, selenium, cadmium sulfide, lead sulfide, antimony (III) sulfide, and silicon carbide were prepared by evaporation, vacuum evaporation, and settling technics.

Preliminary experiments were conducted to demonstrate the suitability of the equipment for pursuit of the investigation of x-irradiated photoconductors and visual registration of x-ray diffraction patterns. The results of these experiments exceeded expectations and have shown the equipment to fulfill the requirements for which it was designed, and to give a highly satisfactory degree of performance.

Observations were made upon the registration of x-ray diffraction patterns upon fluorescent screens viewed by the unaided, dark-rested eye, a simple image tube (CV-147) (7), and a simple iconoscope (RCA-5527) (1) (12). It was found that the particular tubes used were incapable of registering even the most intense diffracted x-ray beams, even under the most favorable conditions, and using very high x-ray intensities (at least by diffraction standards).

Still further experiments upon the direct x-ray sensitivity of the RCA-5527 iconoscope showed that the tube cannot see even direct x-ray beams of very high intensity.

The potential applicability to electronic registration of electron diffraction patterns of picture pickup tubes having image sections and secondary emissive scanned targets, is pointed out.

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The thesis contains viii plus 217 pages, 87 figures, 90 references, and an appendix of parts lists for all the electronic equipment.

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# VITA

Eugene P. Bertin, Jr. was born on October 29, 1921, in Williamsport, Pennsylvania. His family later moved to Muncy, Pennsylvania, and he graduated from the Muncy-Muncy Creek Township High School in 1939. He entered Williamsport-Dickinson Junior College (now Lycoming College) in 1939 and graduated in 1941. After serving in the Army of the United States from June, 1942 until October, 1943, he was employed by the Sylvania Electric Products Company, Inc. at their Williamsport plant. He was first affiliated with the Tube Division, Equipment Construction Department, and later with the Industrial Electronics Division, Engineering and Product Development Department.

He entered the University of Illinois in September, 1946, and received the degree of Bachelor of Science in June, 1948. In September of that year, he entered the Graduate College, receiving the degree of Master of Science in June, 1949. Since September, 1949, he has held a half-time graduate assistantship in the Analytical Division of the Chemistry Department.

In November, 1946, the writer married Phyllis E. Pegg, of Muncy, Pennsylvania.

He is a member of the American Chemical Society, Society of the Sigma Xi, and Phi Lambda Upsilon.

Published articles by the writer are:

"A Simple and Effective Condenser Tester": Radio-Craft (now Radio-Electronics) 14 82-3, 107 (1942).

"Radio Waves and Radio Antennas": *ibid.* 14 728-9, 750-2 (1943); 15 24-5, 56-8 (1943).